Internet Engineering Task Force (IETF)でのハッカソンと Secure Update の技術開発の紹介

2023年5月

直近の活動の紹介

- Internet Engineering Task Force (IETF) で 2 つの活動

1) IETF で標準化ドラフト(Internet-Drafts, I-Ds)のための技術開発と実装
2) I-Ds の著者としてドラフトが正式な標準化文章(RFC)になるよう継続的なアップデート、RFC化はもうすぐ

IETF での技術開発、TEEPの紹介 (1/3)

- Trusted Execution Environment Provisioning (TEEP) Protocol を開発
- https://github.com/ietf-teep/teep-protocol/wiki

Product Solutions Open Source Pricing

ietf-teep / teep-protocol Public

Code Issues 7 Pull requests Actions Projects Wiki Security Insights

Home

Akira Tsukamoto edited this page 3 hours ago · 23 revisions

IETF TEEP Protocol Wiki Page

Introduction

To simplify the life of developers interacting with Trusted Applications in a Trusted Execution Environment (TEE), an interoperable protocol for managing TAs running in different TEEs of various devices is needed - the TEEP protocol.

Introduction, objective and use cases of TEEP

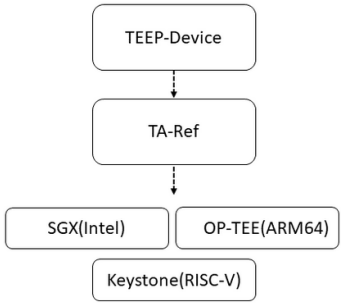
The charter page of the TEEP working group can be found at: https://datatracker.ietf.org/wg/teep/about/

These are the main working group documents:

- TEEP Architecture: https://datatracker.ietf.org/doc/draft-ietf-teep-architecture/
- TEEP over HTTP: https://datatracker.ietf.org/doc/draft-ietf-teep-otrp-over-http/
- TEEP Protocol: https://datatracker.ietf.org/doc/draft-ietf-teep-protocol/

出るまでが長かった
3年ほど遅れた
辛かった

Relationship of TA-Ref and TEEP-Device



Implementation of TEEP Protocol.

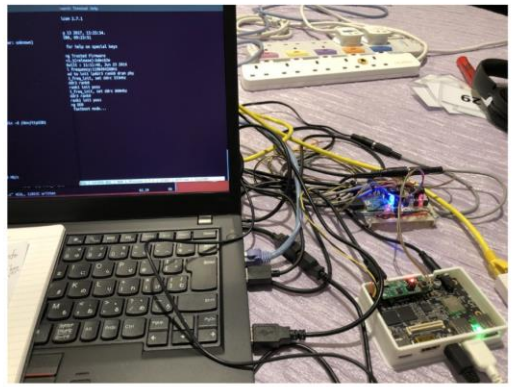
Provides a portable programming environment as an SDK with a subset of the Global Platform Internal API on all SGX (Intel), OP-TEE (ARM64), and Keystone (RISC-V).

There are various TEE implementations such as SGX (Intel), OP-TEE (ARM64), and Keystone (RISC-V).
These implementations share similar feature designs, but each has its own APIs and programming environments.

IETF での技術開発、TEEPの紹介(2/3)

- IETF ハッカソンにて。セコムさんに大感謝。

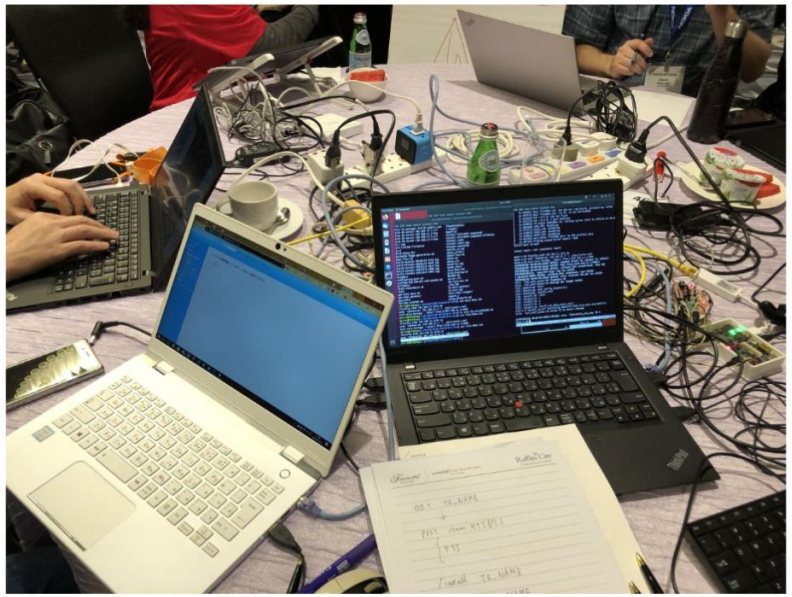
TEEP device



IETF 106 Hackathon - TEEP 7

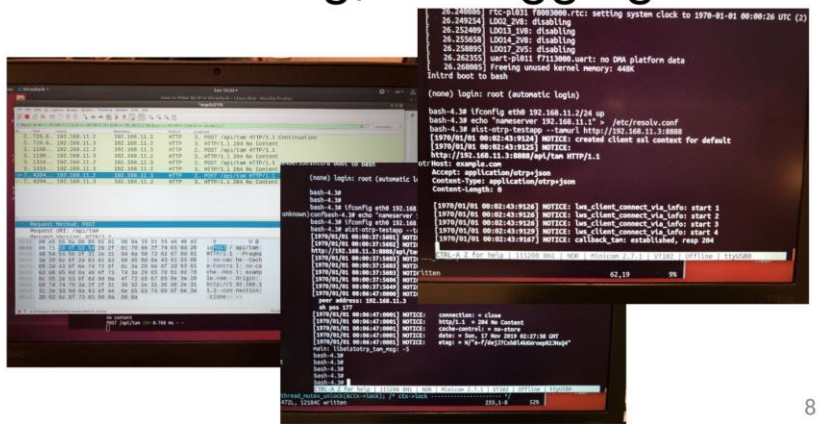
ケーブル
がたくさん

On the Table



IETF 106 Hackathon - TEEP

Hacking, Debugging!



8

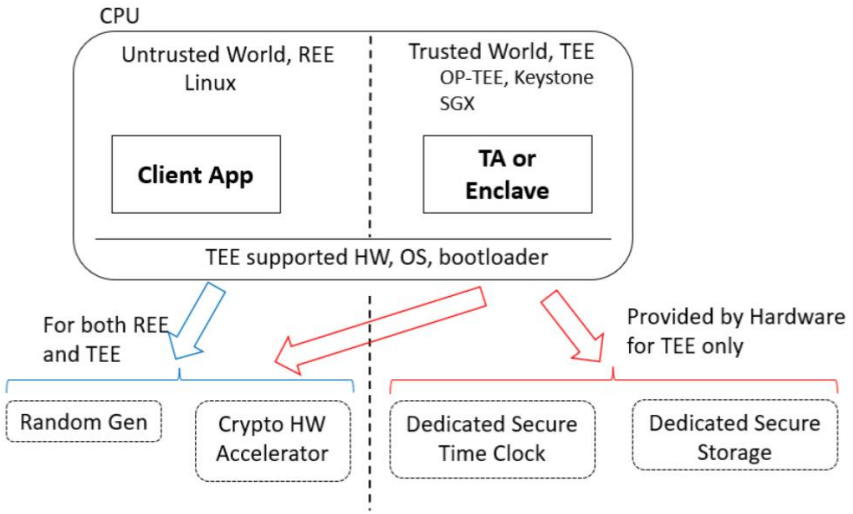
3

IETF での技術開発、TEEPの紹介(3/3)

https://github.com/ietf-teep/teep-protocol/wiki/files/ta-ref-open/ta-ref.pdf

https://github.com/ietf-teep/teep-protocol/wiki/files/teep-device-open/teep-device.pdf

1.1.1 Assumption of hardware features of TA-Ref on TEE



The Secure Time Clock is the date and time clock hardware peripheral which updates monotonically provided separately from regular clock peripheral so the user application and OS on REE could not change the date and/or time. Many certificates of CA, license keys of purchased serial code, hardware enablement keys such as increasing the battery size of the electric cars are bound to the date. The easiest way for end users or attackers phishing the CAs and web sites, using the software and enabling the optional hardware feature without the payment is to change the value of the clock. The concrete date and time is especially important for the telemetry data

IETF の Internet-Draft を日々更新

https://datatracker.ietf.org/doc/draft-ietf-teep-protocol/

https://github.com/ietf-teep/teep-protocol

draft-ietf-teep-protocol-13

TEEP
Internet-Draft
Intended status: Standards Track
Expires: 2 November 2023

H. Tschofenig
M. Pei
Broadcom
D. Wheeler
Amazon
D. Thaler
Microsoft
A. Tsukamoto
1 May 2023

Trusted Execution Environment Provisioning (TEEP) Protocol
draft-ietf-teep-protocol-13

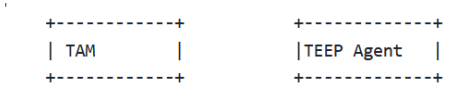
Abstract

This document specifies a protocol that installs, updates, and deletes Trusted Components in a device with a Trusted Execution Environment (TEE). This specification defines an interoperable protocol for managing the lifecycle of Trusted Components.

Status of This Memo

This Internet-Draft is submitted in full conformance with the provisions of BCP 78 and BCP 79.

Internet-Drafts are working documents of the Internet Engineering Task Force (IETF). Note that other groups may also distribute working documents as Internet-Drafts. The list of current Internet-



4. Detailed Messages Specification

TEEP messages are protected by the COSE_Sign1 or COSE_Sign structure as described in Section 8.1. The TEEP protocol messages are described in CDDL format [RFC8610] below.

```
teep-message = $teep-message-type .within teep-message-framework

teep-message-framework = [
  type: $teep-type / $teep-type-extension,
  options: { * teep-option },
  * any; further elements, e.g., for data-item-requested
]

teep-option = (uint => any)

; messages defined below:
$teep-message-type /= query-request
$teep-message-type /= query-response
$teep-message-type /= update
$teep-message-type /= teep-success
$teep-message-type /= teep-error
```

TEEP とは (1/2)

Acronyms

Trusted Execution Environment Provisioning (TEEP)
Software Updates for Internet of Things (SUIT)
Remote ATtestation ProcedureS (RATS)

- Target Audience
  Vendors who develop products with CPU or SoC require Secure Update of software and data

- Lifecycle Management for Trusted Applications (Software) and Personalization data (Data)

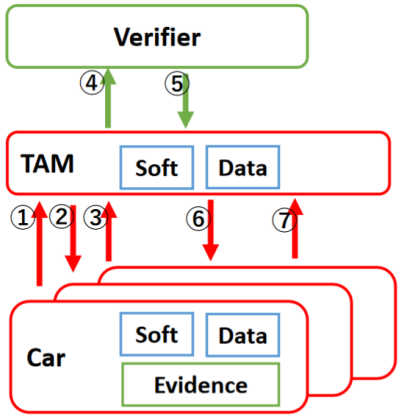
- Main objective is to manage Software and data in IoT devices to have latest version

- Before updates of the Software and Personalization data in IoT , the server check the trustworthiness of the IoT devices remotely whether it is compromised or not

TEEP とは (2/2)

- https://github.com/ietf-teep/teep-protocol/wiki/files/2023-IETF-TEEP-activity-2023-04-18-1.pdf

  • Automotive

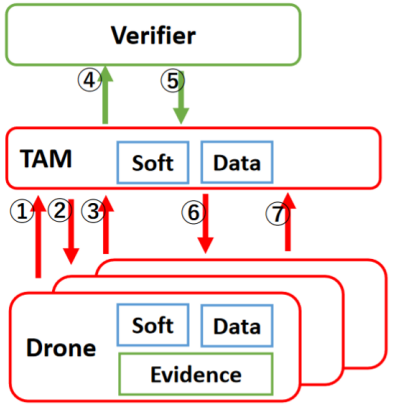


Automotive Manufacture

Operators

Usage
- Unlock Quick Charge
- OTA
- Remote monitor cars
- Remote telemet

• Drone

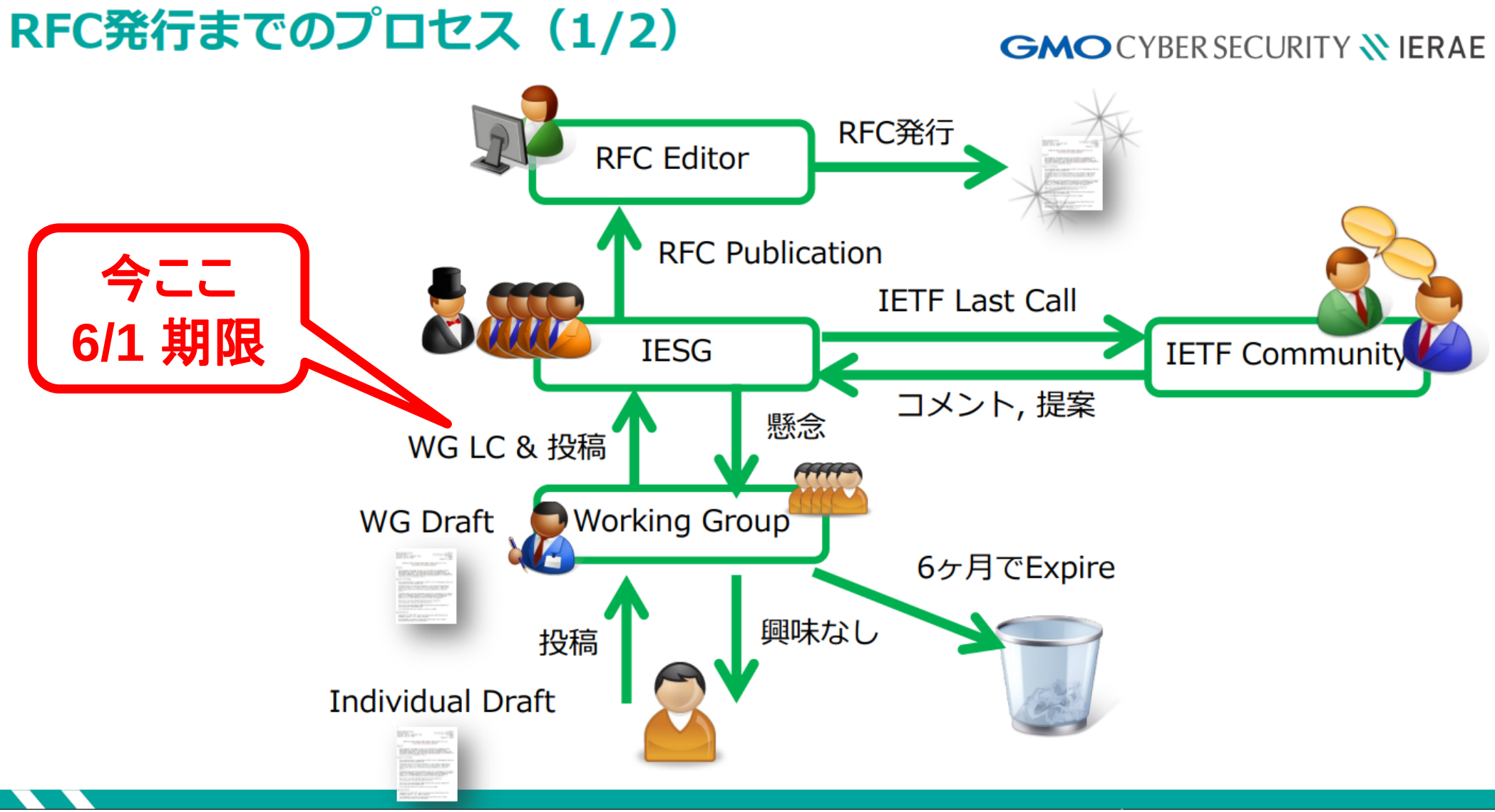


Drone Vendors

Local Government Drone Mgmt Server

Usage
- Install Drone ID app for drone registration
- Disable drone when it falls into enemy hands

I.D が RFC になるまでの流れ (1/2)



I.D が RFC になるまでの流れ (2/2)

RFC発行までのプロセス（2/2）

GMO CYBER SECURITY IERAE

- **Individual Draft**
  - Internet Draft（I-D）を執筆しIETF に投稿したら、まずこのステータス
  - 適切と思われるWGで意見を求める
- **Working Group Draft**
  - WGのCharterに合致かつWG memberからのコンセンサスを得るとWG Draft（WG item）に昇格
  - その後、詳細内容についてMLなどで議論を行い、I-Dのブラッシュアップ
  - WG Last Call を行いフィードバックを反映してIESGへ提出
- **IESG Process**
  - 担当AD による Review 後、IETF Last Call を行い IETF Community 全体からのフィードバックを得る。その後、IESG Member による Review が実施される
- **RFC Editor Process**
  - RFC発行に向けて、フォーマット確認。文章見直しなどの編集作業が実施される

IETF での活動の内容

- 基本的な活動内容は 2002年に見た IETF の活動内容をまねた
- 真似た内容は次ページ以降に

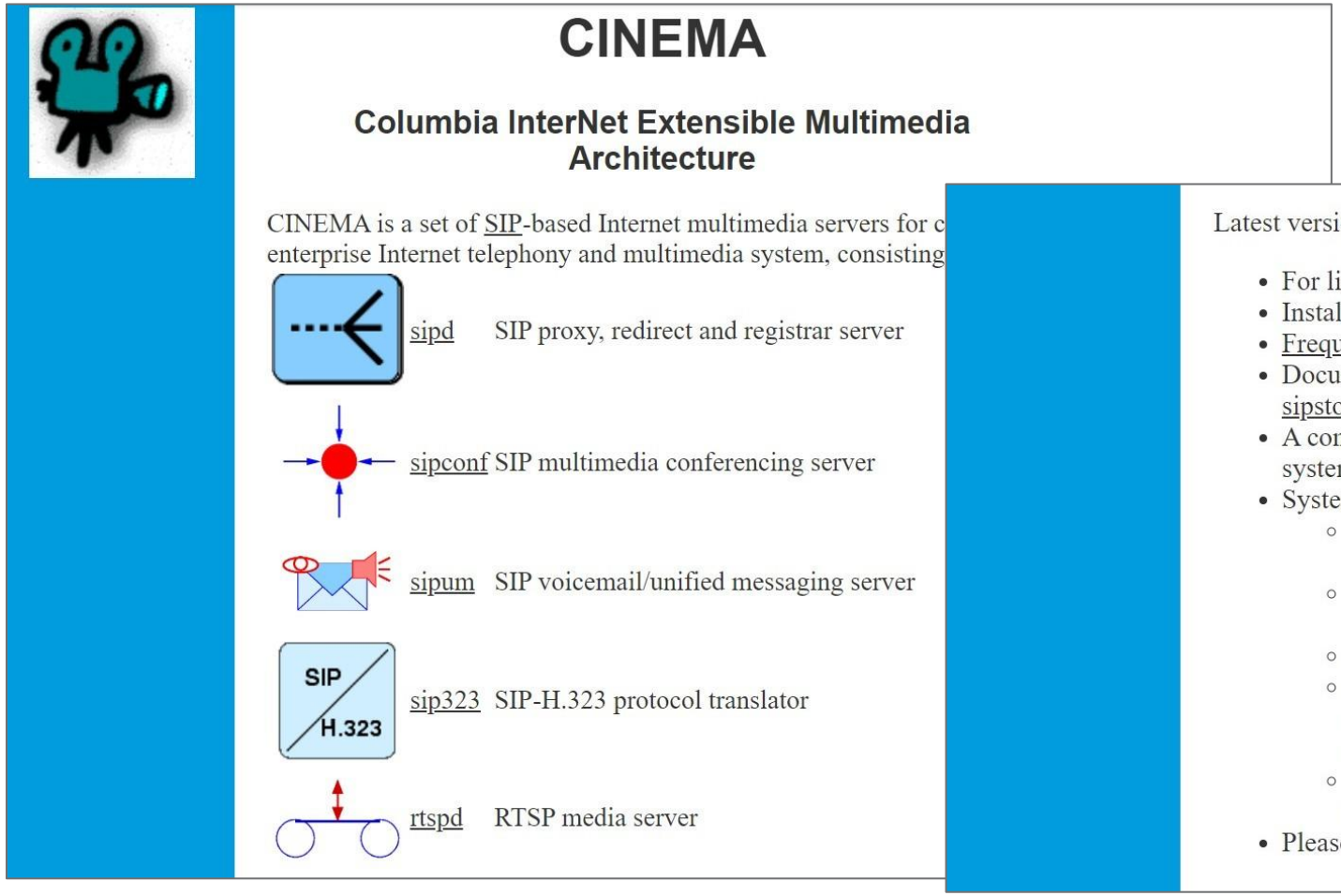
- IETF 開催毎に実装やハッカソンで見つかる課題を標準化ドラフト(Internet-Draft)に反映
- 実装はソフトウェアサプライチェーンを考慮
  1) Docker による開発環境の提供
  2) 全ソースにコピーライト、SPDX 情報、ライセンス条項を記述
  3) Makefile ならびに詳細なビルドドキュメント
  4) Git の全 commit log 提供
  5) CI 用スクリプト提供 (gitlab を使っていた)

大学で IETF 準拠テレビ会議システムのプロジェクトに参加

金が必要だった

今の zoom, teams と同じ機能

2001年に
音声、動画、テキストチャット、
画面共有機能

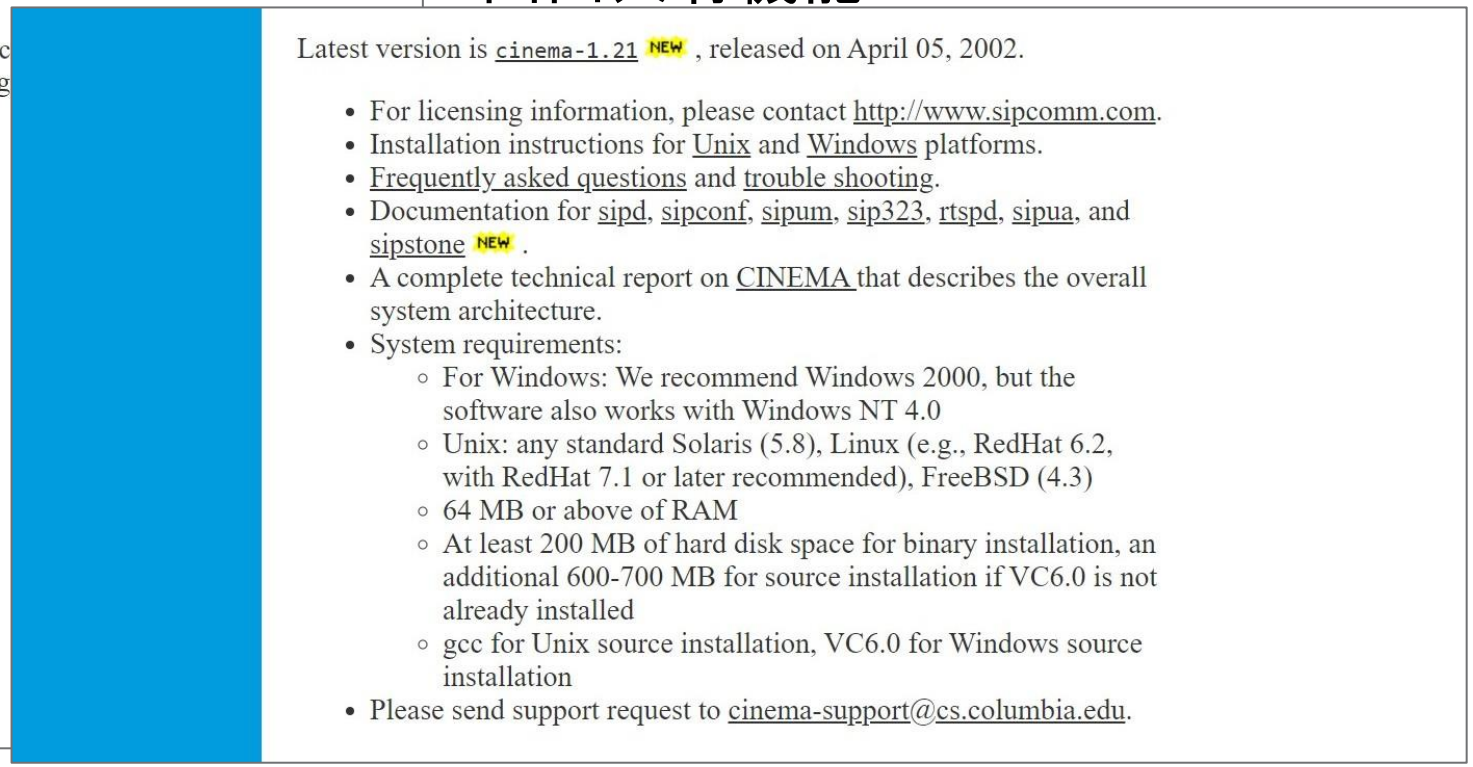


CINEMA

Columbia InterNet Extensible Multimedia Architecture

CINEMA is a set of SIP-based Internet multimedia servers for c
enterprise Internet telephony and multimedia system, consisting

- sipd — SIP proxy, redirect and registrar server
- sipconf — SIP multimedia conferencing server
- sipum — SIP voicemail/unified messaging server
- sip323 — SIP-H.323 protocol translator
- rtspd — RTSP media server



Latest version is cinema-1.21 NEW , released on April 05, 2002.

- For licensing information, please contact http://www.sipcomm.com.
- Installation instructions for Unix and Windows platforms.
- Frequently asked questions and trouble shooting.
- Documentation for sipd, sipconf, sipum, sip323, rtspd, sipua, and sipstone NEW .
- A complete technical report on CINEMA that describes the overall system architecture.
- System requirements:
  - For Windows: We recommend Windows 2000, but the software also works with Windows NT 4.0
  - Unix: any standard Solaris (5.8), Linux (e.g., RedHat 6.2, with RedHat 7.1 or later recommended), FreeBSD (4.3)
  - 64 MB or above of RAM
  - At least 200 MB of hard disk space for binary installation, an additional 600-700 MB for source installation if VC6.0 is not already installed
  - gcc for Unix source installation, VC6.0 for Windows source installation
- Please send support request to cinema-support@cs.columbia.edu.

http://web.archive.org/web/20020607235317/http://www.cs.columbia.edu/IRT/cinema/
https://www.cs.columbia.edu/irt/people/alumni

パケット通信技術でのリアルタイム性と品質確保の難しさ

GoToMeeting Audio Statistics

```
MODE: VoIP

VE:   P M , capture s/w/e 0/0/0, play w/e 0/0, drop 1
VOL:   in 0%, out 100%
SPECH: in -24dBm0, out 0dBm0
NOISE: in -81dBm0, out 0dBm0
AGC:   gain 0dB, maxLv 255, clip 0ms, convergeLevel 0sec, convergeMic 0sec
ECHO:  ERL 0, ERLE 0, RERL -100, A_NLP -100
RES_EC:corr 0%, conf 0%, likelihood 0%, delay median 0ms, std 0
AQE:    80%
CODEC: OPUS (33Kbps, 20ms)
DELAY: est 85ms play 42ms
RTP:   avg 2ms, max 24ms, dro 0
RTCP:  rtt 0ms
RTCP:  frc 0%, cum 42, ext 92984
JB:    cur 35ms, tar 20ms
JB:    los 0.0%, dis 0.0%
JB:    exp 0.0%, pre 0.0%, acc 0.0% AuDrpMs 0, AuDrp 0

FLAGS: AdvNsSupp 1, ReTx 0

PIPE: eSpeakerRole, connected using UDP S R

TRAN: RTP
RTP:  in 0Kbps, 92987pkts, 7488KB, dro 0pkts
RTP:  out 0Kbps, 0pkts, 0KB, dro 0pkts
RTP:  in jit 0ms, los 0.0%/0.0%
RTP:  out jit 0ms, los 0.0%/0.0%
RTCP: in 0pkts, 0KB, dro 0pkts
RTCP: out 379pkts, 0KB, dro 0pkts


Vincent [54]

SYS:  9% (3%/6%), proc 0%, dpc 2%, speed 95%
PROC: ca 1%, vc 0% (unk 0%), ui 0% (unk 0%), sum 1%
VOIP:  7%/ 7%/ 7% ->  7% ( 7%/ 0%), 0%, audiodg 0%
SCRE:  6%/12%/25% -> 25% (25%/ 0%), est 0%, up 0%, down 0%
VIDO:  0%/ 0%/ 0% ->  0% ( 0%/ 0%), est 0%, enc 0%, dec 0%, cap 0%, ren 0% mms -1%

BW:   up req min    0Kbps, dem    0Kbps, grant sho    0Kbps, lon    0Kbps
BW:   dn req min    0Kbps, dem    0Kbps, grant sho    0Kbps, lon    0Kbps
BW:   curr: rtt 177ms, ud 88ms, ul 0%, dd 87ms, dl 0%
BW:   best: rtt 173ms, ud 86ms, ul 0%, dd 86ms, dl 0%

Video Session: eConferenceIdle
```

RTPQOS

NAME

rtpqos - QoS measuring tool for RTP packets

SYNOPSIS

`rtpqos [options] remote_host/local_port[/remote_port]`

DESCRIPTION

This is a tool to measure QoS parameters, delay, round trip time, diff, jitter and loss, for RTP packets.

The rtpqos will generate packets with a specific byte pattern which sounds like a periodic beep. The byte pattern will be used as a signature for matching packets later. After sending each packet, it stores the signature of the packet in a table, along with sent timing information.

Then rtpqos listens to packets on a given network address. It determines which original packet received belongs to sent packets by using the embedded byte pattern in the payload.

Calculate and updates delay, jitter and loss statistics to a file.

Consequently, following parameters are created and obtained from the tool, in addition to the information contained in the original RTP headers.

1. From RTP packets:
    1. total round trip delay
       includes processing time at remote.
    2. interval_from_prev_packet
    3. diff
       This is a fraction of deviance from the ideal arrival time.
    4. jitter
       Uses normal 1/16 noise reduction ratio of the diff.
    5. loss
       It is incremented whenever the embedded id jumps.
2. From RTCP packets:
    1. network round trip time
       This is computed from RTCP_RR_arrival_time - DLSR - LSR.
       Contrary to the "total round trip time", it measures round trip time on the network without including processing time at remote.

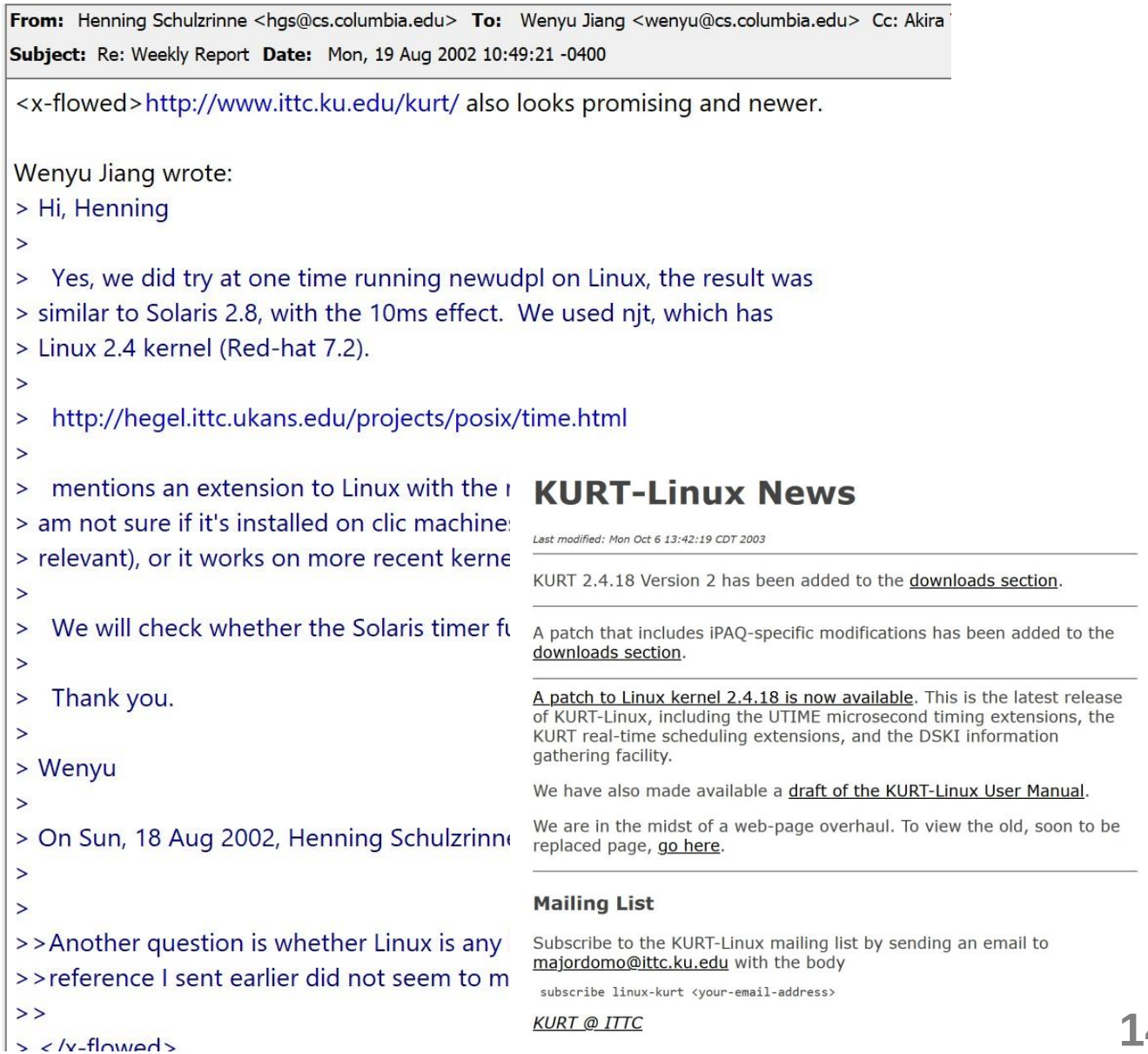
http://www.cs.columbia.edu/~hgs/research/projects/rtpqos/rtpqos-1.0/rtpqos.html

Linux kernel のリアルタイム性に苦しむ

- 当時の Linux kernel はタイマーが 10ms の解像度しかなく RTP パケットの20ms 毎の送信が困難だった。

- Henning 先生より The University of Kansas のリアルタイム性を上げるプロジェクトを参考に自分たちで kernel を触ることに

- 1995年に友人が Linux と FreeBSD を私の PC にインストールして以来、kernel は触れるようになりたかった。



From: Henning Schulzrinne <hgs@cs.columbia.edu> **To:** Wenyu Jiang <wenyu@cs.columbia.edu> Cc: Akira
Subject: Re: Weekly Report **Date:** Mon, 19 Aug 2002 10:49:21 -0400

<x-flowed>http://www.ittc.ku.edu/kurt/ also looks promising and newer.

Wenyu Jiang wrote:
> Hi, Henning
>
> Yes, we did try at one time running newudpl on Linux, the result was
> similar to Solaris 2.8, with the 10ms effect. We used njt, which has
> Linux 2.4 kernel (Red-hat 7.2).
>
> http://hegel.ittc.ukans.edu/projects/posix/time.html
>
> mentions an extension to Linux with the
> am not sure if it's installed on clic machine
> relevant), or it works on more recent kerne
>
> We will check whether the Solaris timer fu
>
> Thank you.
>
> Wenyu
>
> On Sun, 18 Aug 2002, Henning Schulzrinne
>
>
>>Another question is whether Linux is any
>>reference I sent earlier did not seem to m
>>
> </x-flowed>

KURT-Linux News

Last modified: Mon Oct 6 13:42:19 CDT 2003

KURT 2.4.18 Version 2 has been added to the downloads section.

A patch that includes iPAQ-specific modifications has been added to the downloads section.

A patch to Linux kernel 2.4.18 is now available. This is the latest release of KURT-Linux, including the UTIME microsecond timing extensions, the KURT real-time scheduling extensions, and the DSKI information gathering facility.

We have also made available a draft of the KURT-Linux User Manual.

We are in the midst of a web-page overhaul. To view the old, soon to be replaced page, go here.

Mailing List

Subscribe to the KURT-Linux mailing list by sending an email to majordomo@ittc.ku.edu with the body

```
subscribe linux-kurt <your-email-address>
```

KURT @ ITTC

インターネット回線の混雑状況を再現

NEWUDPL

NAME

newudpl - Network Emulator With UDP Link

SYNOPSIS

```
newudpl [-[v|vv]] [-p [recv_port]:[send_port]]

      [-i sorce_host[[:|/][port|*]]] [-o dest_host[[:|/]port]]
      [-s link_speed] [-d delay] [-e Ethernet_speed] [-q queue_buf_size]
      [-[B|L|C|U|O] error_rate]
```

DESCRIPTION

This is a tool to create various condition of packet switching behavior artificially for UDP packets.

The emulator receives UDP packets on a designated port and then delays them, drops some randomly, corrupts the content, swaps the order of sending and emulates a finite-bandwidth link by queuing packets. It should be useful to examine an efficiency of network protocols or codecs.

INSTALLATION

Source codes are available from:
http://www.columbia.edu/~at541/src

Unix/Unix like system
To build, unpack the tar file, then type:

```
./configure
make
```

Windows98/NT
Microsoft VC++ 6
Open newudpl.dsw under msc\ and just press F7.

Borland C++ builder
Open newudpl_bcb.bpr under bcb\ and just press F9.

I have only tested on SunOS 5.7, 5.8 system and Linux but it should compile on other Posix-compliant platforms.

下記のパラメーターを設定可能

- パケットロス
- 遅延
- パケットの順不同到着
- 各パケットの到着時間の揺れ（jitter）

次ページの rtpqos を使って音声と動画の品質を最適化

授業の教材になりうれしかった

http://www.cs.columbia.edu/~hgs/research/projects/newudpl/newudpl-1.4/newudpl.html

音声・動画データの品質計測

RTPQOS

NAME

rtpqos - QoS measuring tool for RTP packets

SYNOPSIS

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DESCRIPTION

This is a tool to measure QoS parameters, delay, round trip time, diff, jitter and loss, for RTP packets.

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1. From RTP packets:
    1. total round trip delay
       includes processing time at remote.
    2. interval_from_prev_packet
    3. diff
       This is a fraction of deviance from the ideal arrival time.

RTP と RTCP パケットから下記のパラメーターを計測可能

- 往復の遅延時間
- 理想到着時間からの実際の到着時間のずれ（diff）
- 各パケットの到着時間の揺れ（jitter）
- パケットロス

http://www.cs.columbia.edu/~hgs/research/projects/rtpqos/rtpqos-1.0/rtpqos.html

乱数生成関数のランダム性で苦労する

```
21 ↓
22 /** random function.↓
23  * returns uniform distributed random num
24  * but it is slower then ANSI rand() func
25  * From↓
26  * 'Numerical Recipes in C'↓
27  *  The Press Syndicate of the University
28 float ran1(long *idum);↓
29 ↓
30 /** binomial random function.↓
31  * returns random number according to binomial-distribution.↓
32  * From↓
33  * 'Numerical Recipes in C'↓
34  *  The Press Syndicate of the
35 int bnldev(float pp, int n, lo
36 ↓
37 ↓
38 /** Gilbert random function.↓
39  * returns 1 for packet loss,
40 int gilbRand(float pc, float p
41 ↓
```

自分で作った乱数生成ライブラリ

```
Schulzrinne, et al.          Standards Track                    [Page 85]

RFC 3550                            RTP                         July 2003


   o  getdomainname(),

   o  getwd(), or

   o  getrusage().

" video or audio sa
rs, but care must be taken to avoid using a turned-off
phone or blinded camera as a source [17].

f this or a similar routine is recommended to generate the
al seed for the random number generator producing the RTCP
d (as shown in Appendix A.7), to generate the initial values for
equence number and timestamp, and to generate SSRC values.
 this routine is likely to be CPU-intensive, its direct use to
ate RTCP periods is inappropriate because predictability is not
sue.  Note that this routine produces the same result on
ted calls until the value of the system clock changes unless
rent values are supplied for the type argument.
```

IETF RTP プロトコル RFC での乱数生成ガイド

```
/*
 * Generate a random 32-bit quantity.
 */
#include <sys/type
#include <sys/time
#include <unistd.h
#include <stdio.h>
#include <time.h>
#include <sys/utsn
#include "global.h
#include "md5.h"

#define MD_CTX MD5_CTX
#define MDInit MD5Init
#define MDUpdate MD5Update
#define MDFinal MD5Final

static u_long md_32(char *string, int length)
{
    MD_CTX context;
    union {
        char   c[16];
        u_long x[4];
    } digest;
    u_long r;
    int i;

    MDInit (&context);
```

IETF RTP プロトコル RFC 乱数生成のコード例

MD5 のセキュリティバグ発見につながる

一様分布する乱数生成関数は遅い
コメントアウトしたら EU から疑われた

md5 実装にセキュリティバグ見つける

```
112   operation, processing another message block, and updating the
113   context.
114  */
115 void MD5Update (context, input, inputLen)
116 MD5_CTX *context;                                        /* context */
117 unsigned char *input;                                /* input block */
118 unsigned int inputLen;                     /* length of input block */
119 {
120   unsigned int i, index, partLen;

121
122   /* Compute number of bytes mod 64 */
123   index = (unsigned int)((context->count[0] >> 3) &

124
125   /* Update number of bits */
126   if ((context->count[0] += ((UINT4)inputLen << 3))
127     context->count[1]++;
128   context->count[1] += ((UINT4)inputLen >> 29);

129
130   partLen = 64 - index;

131
132   /* Transform as many times as possible.  */
133   if (inputLen >= partLen) {
134     memcpy
135       ((POINTER)&context->buffer[index], (POINTER)in
136     MD5Transform (context->state, context->buffer);
```

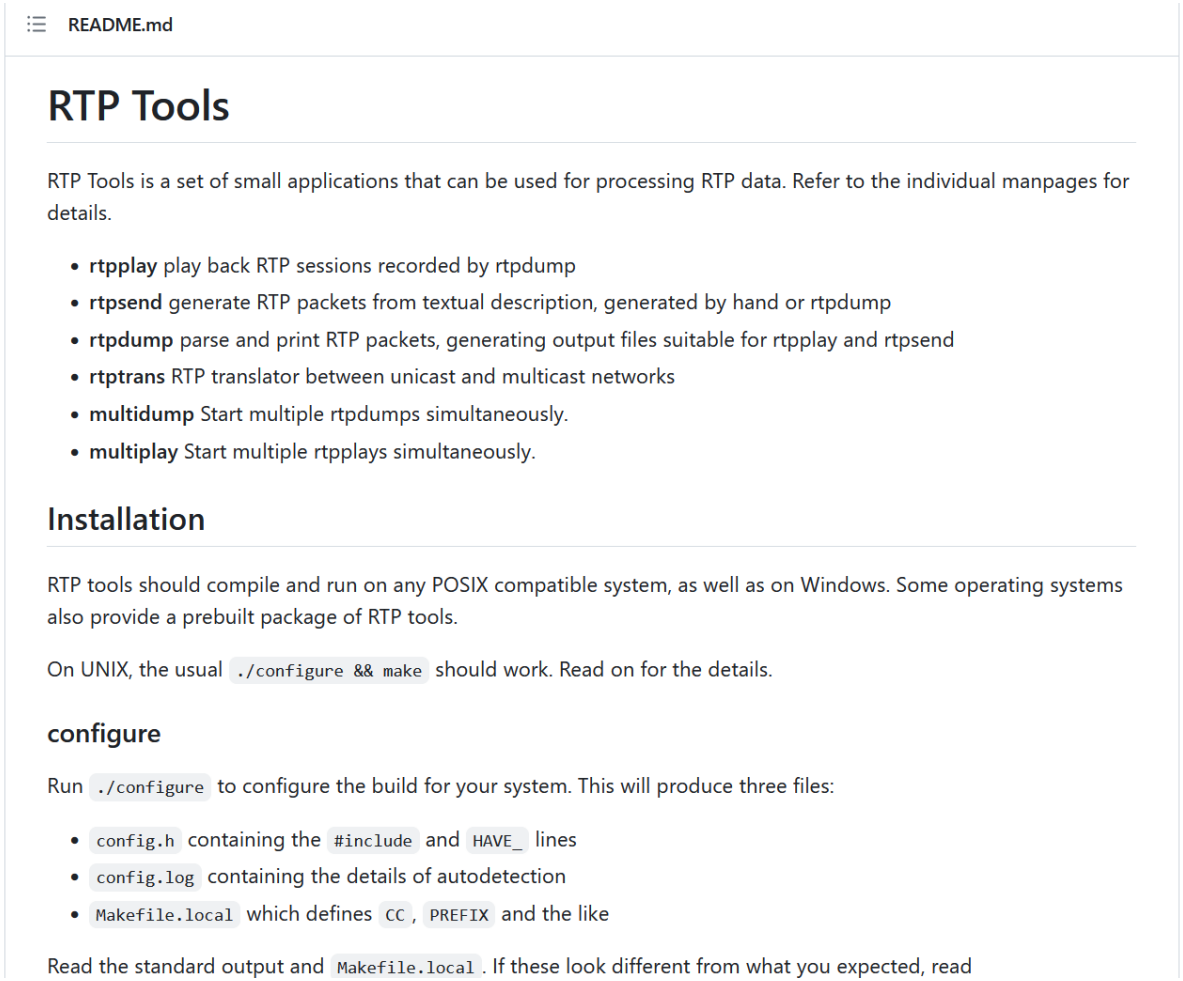
```
137
138     for (i = partLen; i + 63 < inputLen; i += 64)
139       MD5Transform (context->state, &input[i]);

140
141     index = 0;
142   }
143   else
144     i = 0;

145
146   /* Buffer remaining input */
147   /* fixed by Akira Tsukamoto 04/04/2002 */
148   if (i >= inputLen)
149     return;
150   /* end fix */
151   memcpy
152     ((POINTER)&context->buffer[index], (POINTER)&input[i],
153     inputLen-i);
154 }
```

今でいう CVE に相当

TEEP Protocol の技術開発の傍ら

- AIST で rtptools のメンテナーをしたかった
  - https://github.com/irtlab/rtptools

RFC3550
RTP:
A Transport Protocol for Real-Time Applications



README.md

RTP Tools

RTP Tools is a set of small applications that can be used for processing RTP data. Refer to the individual manpages for details.

- **rtpplay** play back RTP sessions recorded by rtpdump
- **rtpsend** generate RTP packets from textual description, generated by hand or rtpdump
- **rtpdump** parse and print RTP packets, generating output files suitable for rtpplay and rtpsend
- **rtptrans** RTP translator between unicast and multicast networks
- **multidump** Start multiple rtpdumps simultaneously.
- **multiplay** Start multiple rtpplays simultaneously.

Installation

RTP tools should compile and run on any POSIX compatible system, as well as on Windows. Some operating systems also provide a prebuilt package of RTP tools.

On UNIX, the usual `./configure && make` should work. Read on for the details.

configure

Run `./configure` to configure the build for your system. This will produce three files:

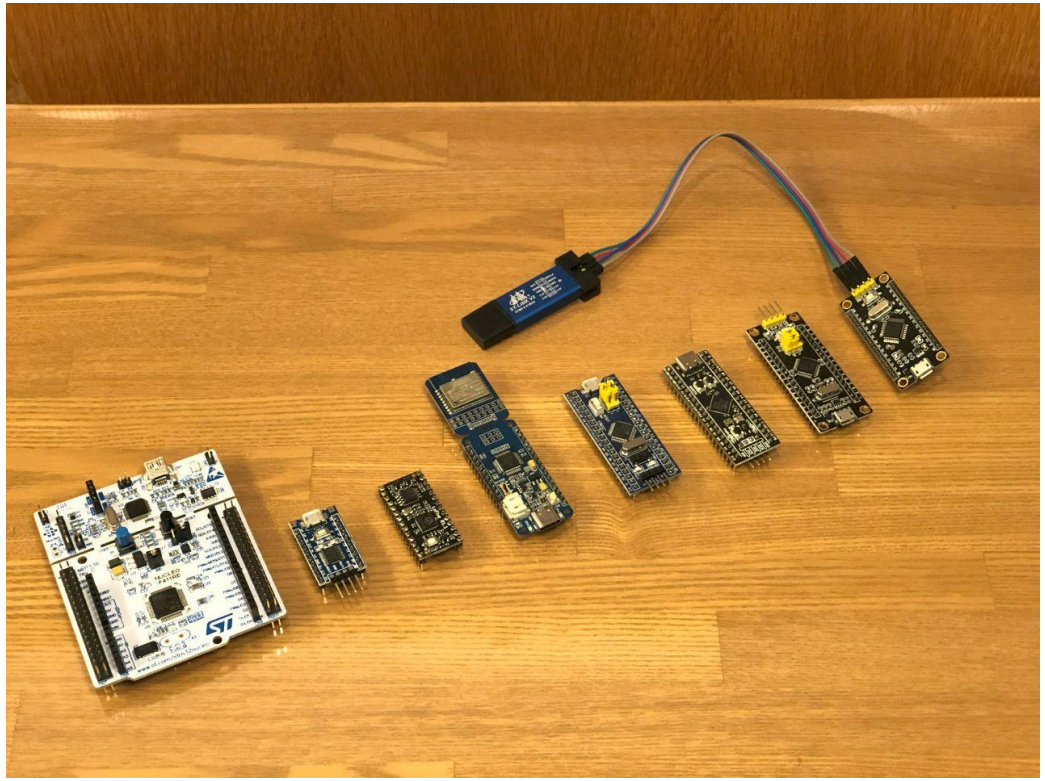
- `config.h` containing the `#include` and `HAVE_` lines
- `config.log` containing the details of autodetection
- `Makefile.local` which defines `CC`, `PREFIX` and the like

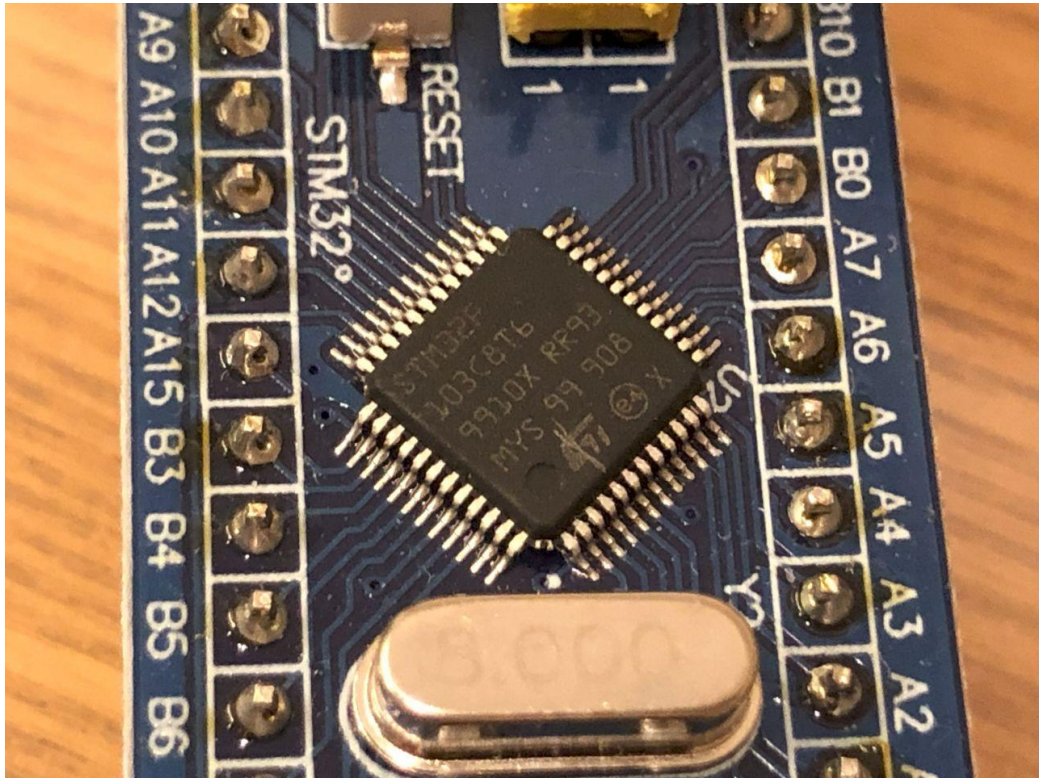
Read the standard output and `Makefile.local`. If these look different from what you expected, read

その他の活動 (1/2)

STM32 Blue Pill, Black Pill を Arduino IDE を使わずに
コマンドラインで開発できる環境を提供することを目的

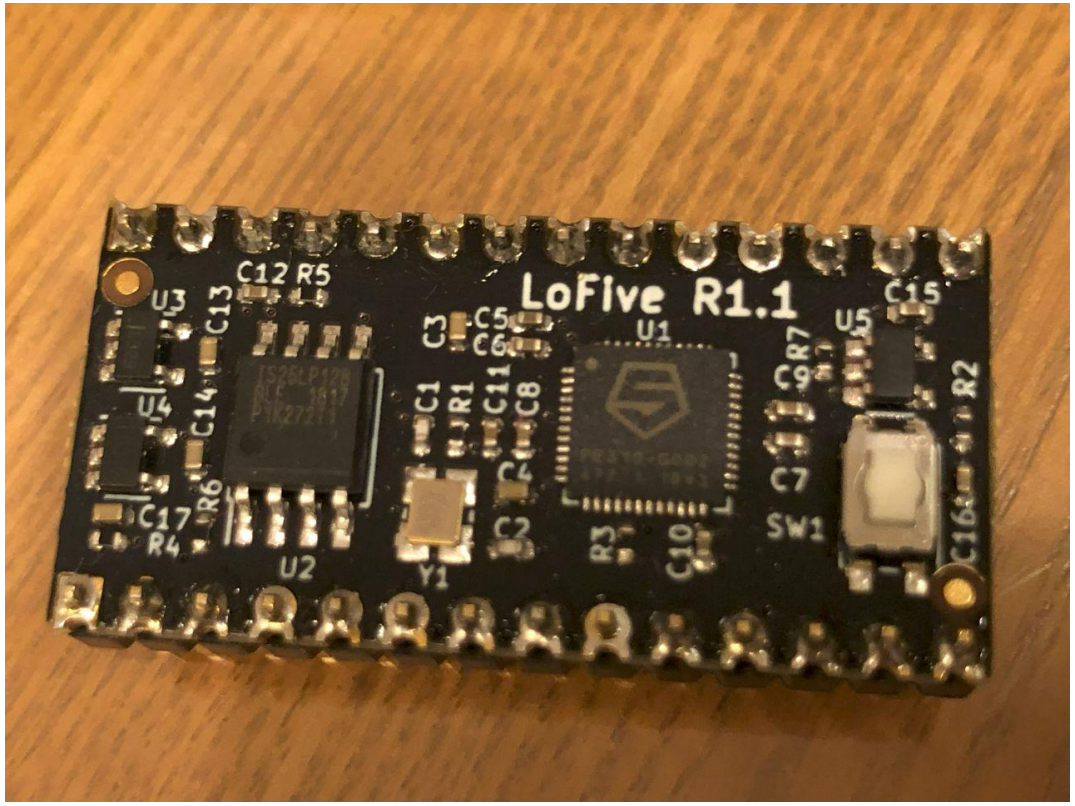
https://github.com/mcd500/arduino-commandliners



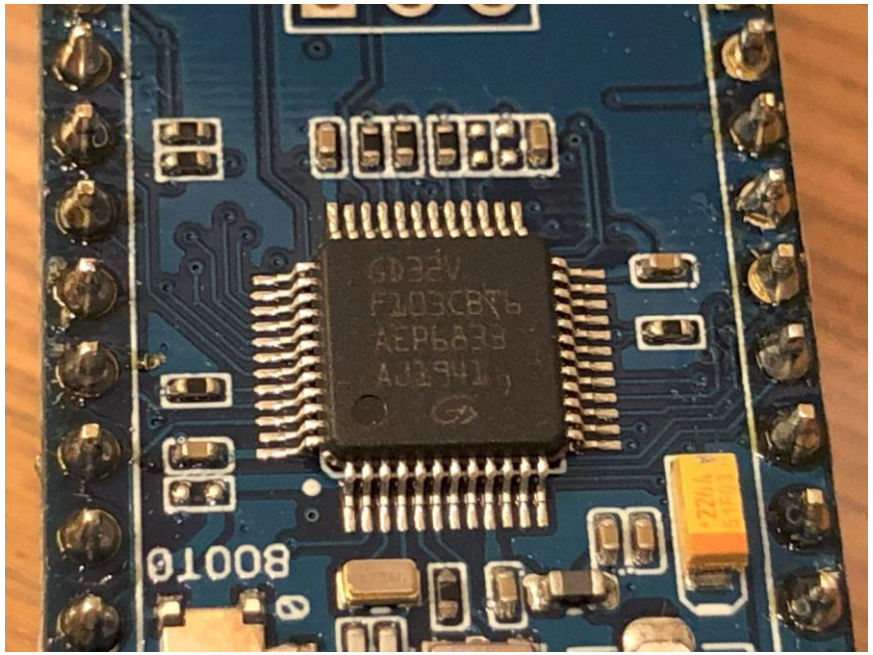


その他の活動 (2/2)

- 将来的に他の STM32 や RISC-V チップもサポートしたい



SiFive FE310



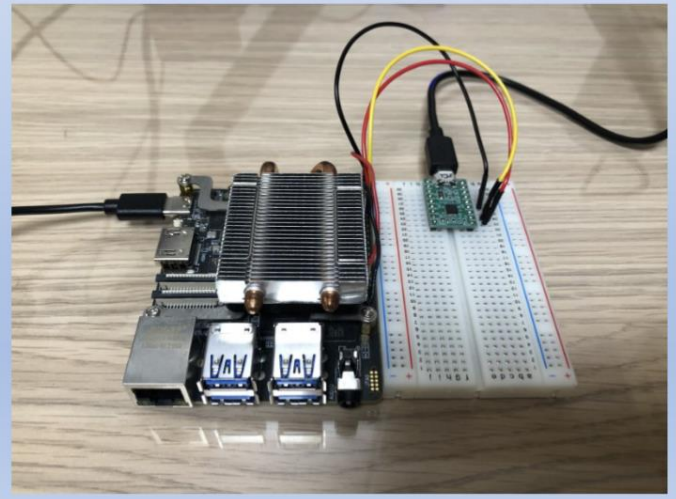
GD32VF103

RISC-V の高速化 (1/3)

- https://static.sched.com/hosted_files/riscvsummit2021/fe/2021-12-05-RISC-V-Summit-BOF-ucopy-AkiraTsukamoto-4.pdf
- CPU 使用率が 34.69% (memcpy), 33.84% (copy_to_user) 計68.53% と極端に高く、これが原因でネットワーク速度が遅くなっていた。

What was observed on RISC-V RV64 boards

- Starlight
  - SoC: StarFive JH7100
  - Core: SiFive U74 (Dual core)

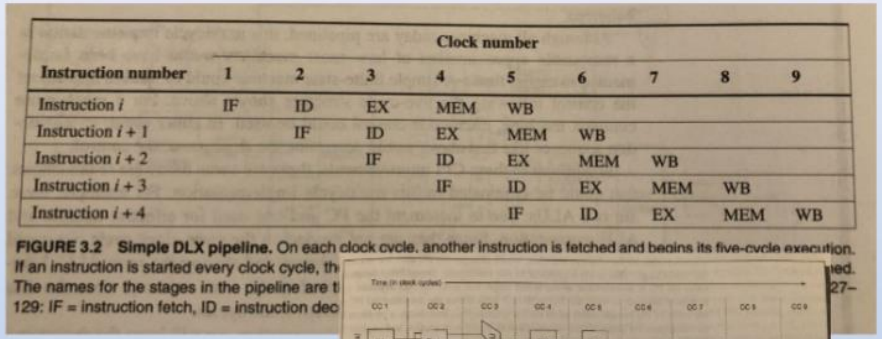


- Workload of Network benchmark
  - iperf3 -u -b 1000M --length 6500 -c 192.168.1.112
- On starlight, similar on Unmatched
  - perf top -Ue task-clock

```
Samples: 35K of event 'task-clock', 4000 Hz, Event count (
 34.69%  [kernel]  [k] memcpy
 33.84%  [kernel]  [k] __asm_copy_to_user
  2.28%  [kernel]  [k] sifive_l2_flush64_range
  1.58%  [kernel]  [k] dev_gro_receive
  1.41%  [kernel]  [k] skb_gro_receive
  1.28%  [kernel]  [k] memset
  0.97%  [kernel]  [k] _raw_spin_unlock_irqrestore
  0.86%  [kernel]  [k] page_pool_put_page
  0.75%  [kernel]  [k] finish_task_switch.isra.0
  0.66%  [kernel]  [k] __skb_datagram_iter
  0.63%  [kernel]  [k] inet_gro_receive
  0.60%  [kernel]  [k] enh_desc_get_rx_status
```

RISC-V の高速化 (2/3)

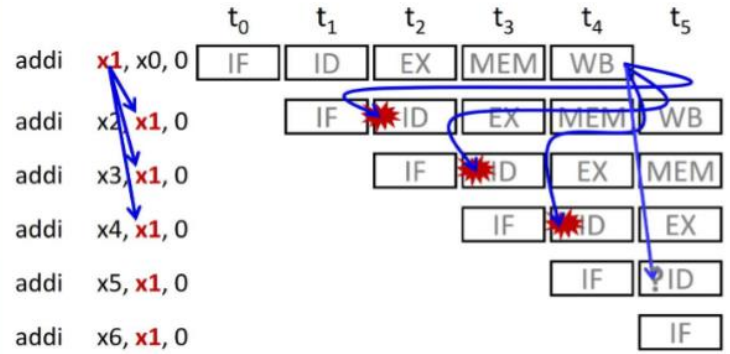
“Computer Architecture: A Quantitative Approach”



Instruction number	Clock number 1	2	3	4	5	6	7	8	9
Instruction *i*	IF	ID	EX	MEM	WB				
Instruction *i* + 1		IF	ID	EX	MEM	WB			
Instruction *i* + 2			IF	ID	EX	MEM	WB		
Instruction *i* + 3				IF	ID	EX	MEM	WB	
Instruction *i* + 4					IF	ID	EX	MEM	WB

FIGURE 3.2 Simple DLX pipeline. On each clock cycle, another instruction is fetched and begins its five-cycle execution. If an instruction is started every clock cycle, th… The names for the stages in the pipeline are t… 129: IF = instruction fetch, ID = instruction dec…

Dependency and Hazard: e.g. RAW



https://users.ece.cmu.edu/~jhoe/course/ece447/S10handouts/L08.pdf

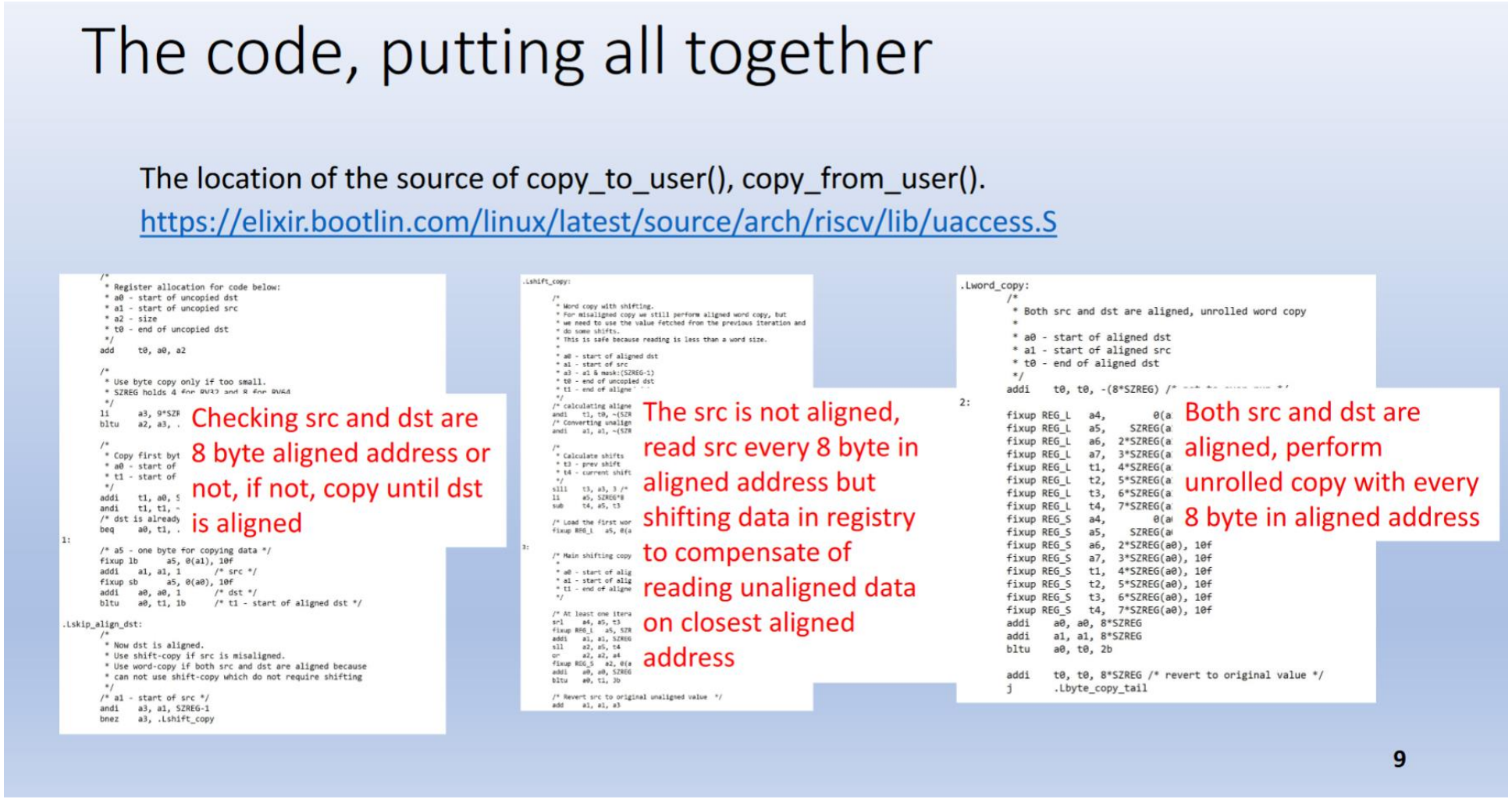
Describes condition of read after write data hazard (RAW)

Able to predict U74 would likely to have 3 pipeline stall for RAW from 4 cycle load use
Good to study on good book!

RISC-V の高速化 (3/3)

ただのコピー関数なのに、ソースのサイズがやたら大きい、RISC系 CPU の特徴

- https://elixir.bootlin.com/linux/latest/source/arch/riscv/lib/uaccess.S



RISC-V で苦労したところ

- 業界のニーズにミスマッチが多い。
- RISC-V はオープンソース？
  - 技術的には RISC-V はオープンソースでは無いです。
  - RISC-V の命令セット (Instruction Set Architecture, ISA)が公開されている、オープン規格であるのが真相。
    - Krste Asanovic 先生は Open Specification と呼ぶ
      https://www.youtube.com/watch?v=RrVRMFjYti0&t=696s
    - David Patterson 先生は Open Standard と呼ぶ
      https://riscv.org/blog/2023/03/top-ten-fallacies-about-risc-v/

- オープンソースは何がメリット？
  - 盛り上がったプロジェクトは開発速度が速い、それに尽きる。
  - GAFAM の体力をもってしてもクローズドな開発では追い付かない。
  - 半導体企業などプラットフォームをとりたい企業が有効活用。
  - もちろん各企業のビジネスでの取り組みであるため、すべてをオープンソースにはしない。

- 日本の半導体業界
  - 海外の技術や製品を買ってくるだけの話になりがちで、、、